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(54) **Steel cords for the reinforcement of rubber article**

Stahlseile zur Verstärkung elastomerer Erzeugnisse

Câbles d'acier pour le renforcement d'articles en caoutchouc

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Description

[0001] This invention relates to steel cords having improved fatigue resistance and retention of tensile strength, as well as to heavy duty pneumatic radial tires for trucks and buses and light trucks having an improved tire durability by using such steel cords as a carcass ply cord thereof.

[0002] In general, steel filaments constituting steel cord fret with each other during running of a tire, so that the sectional area of the steel filament is reduced due to the fretting to lower the tensile strength of the steel cord. If the reduction of the sectional area in the steel filament is considerable only in a part of the cord, such a steel filament is apt to be broken by shock in tension or repetitive bending. Once the steel filament is broken, the tensile stress in the remaining steel filaments increases and hence fatigue breakage of the steel cord is undesirably promoted.

[0003] In order to enhance the durability of the steel cord, it is necessary to avoid premature breakage of steel filaments in a part of the steel cord. That is, it is desirable to uniformly decrease the strength of the steel filaments in the cord.

[0004] The present inventor has examined the decrease of filament strength in the carcass ply cord during the running of a tire with respect to steel cords having a layer twisting construction and stabilized by spirally wrapping a wrap filament, and confirmed that the decrease of filament strength in an outermost sheath layer of the cord is extremely large and results mainly from fretting with the wrap filament.

[0005] Now, the inventor has further examined the steel cords while removing the wrap filament therefrom for the prevention of the fretting, and confirmed that the decrease of filament strength in the outermost sheath layer of the cord is less because fretting with the wrap filament is not caused owing to the absence of the wrap filament.

[0006] If a wrap filament is not used, however, the binding of the cord becomes poor and the steel filaments constituting the cord become scattered when the cord is extremely bent, and as a result a phenomenon of breaking the steel filament when abnormal input is applied to a part of the steel filaments is observed in the cord of two layer twisting construction. In this case, the breaking life of the cord is largely shortened as compared with the stabilized steel cord wrapped with the wrap filament. As a result, it is required to restrain the cord by suitable means in order to prevent the degradation of cord life due to extreme bending input.

[0007] Attention is also drawn to the disclosure of US-A-4 781 016.

[0008] It is, therefore, an object of the present invention to prevent the decrease of filament strength in the outermost sheath layer of the steel cord as a carcass ply cord by mitigating fretting between the wrap filament and the steel filament in the outermost sheath layer while maintaining the binding of the steel filaments in the cord and controlling abnormal input to the steel filament during large bending of the cord.

[0009] According to the invention, there is provided a steel cord for the reinforcement of rubber articles, having a three-layer twisting construction comprising a core layer comprised of a single steel filament, a first sheath layer comprised of six steel filaments arranged around the core layer, and a second sheath layer comprised of steel filaments of number subtracted by 1 or 2 filaments from the maximum steel filament number arranged on a circumscribed circle of the first sheath layer, in which the steel filaments in the first and second sheath layers are twisted in the same twisting direction at a different twisting pitch without using a wrap filament, and filament diameters of the core layer and the sheath layers satisfy the following relationships:

$$Ds < Dc \leqq 0.20$$

$$Ds \times 1.06 \leqq ((Dc + Ds) \times \pi)/6 \leqq Ds \times 1.1$$

wherein Ds is filament diameter of the sheath layer (mm) and Dc is filament diameter of the core layer (mm).

[0010] In a preferable embodiment of the invention, the above steel cords are applied to a carcass ply in a heavy duty pneumatic radial tire having an aspect ratio of not more than 80%, whereby decrease of filament strength due to fretting between the steel filament in the outermost sheath layer and a wrap filament can be controlled while maintaining the binding of the steel filaments in the cord.

[0011] The invention will be further described with reference to the accompanying drawings, wherein:

Fig. 1 is a diagrammatic sectional view of an embodiment of a steel cord having a 1 + 6 + 11 layer twisting construction according to the invention;
Fig. 2 is a diagrammatic sectional view of a steel cord having a1 + 6 + 12 + 1 layer twisting construction as a comparative example; and
Fig. 3 is a schematic view showing fretting depth of a steel filament.

[0012] In this type of layer twisted cord, the non-uniformity in the decrease of filament strength, particularly the extreme decrease of filament strength in the outermost sheath layer of the cord during running of a tire, is due to the fact that the twisting direction of the wrap filament is different from the twisting direction of the steel filament in the outermost sheath layer. The contact area between the steel filament in the outermost sheath layer and the wrap filament is small and the contact pressure per unit area becomes large.

[0013] Further, torsional input is created in the carcass ply cord at the ground contact region of the tire in the longitudinal direction during the running of the tire. If the torsional input is created in a direction disentangling the twisted structure of the outermost sheath layer, the torsional input is created in the wrap filament in a more twisting direction to cause relative movement between the steel filament and the wrap filament when the twisting direction of the wrap filament is different from the twisting direction of the steel filament in the outermost sheath layer. When large relative movement is caused in addition to the large contact pressure, fretting between the wrap filament and the steel filament in the outermost sheath layer is promoted to reduce the sectional area of the steel filament and hence decrease of filament strength in the outermost sheath layer is caused.

[0014] Similarly, when the twisting directions of the first sheath layer and the second sheath layer in the cord are opposite, the contact pressure between the steel filaments of these layers becomes large to promote fretting between these steel filaments and hence the sectional area of the steel filament is reduced to cause decrease of filament strength in these sheath layers.

[0015] Furthermore, plated film formed on the surface of the steel filament is peeled off at a portion reducing the sectional area of the steel filament (fretted portion), and hence the steel filament is apt to be corroded at this portion, which badly affects the resistance to corrosion fatigue in the cord.

[0016] When steel cord of layer twisting construction is formed by twisting the steel filaments of the first and second sheath layers in the same direction without the use of the wrap filament, decrease of filament strength is not caused. However, when the steel filaments are closely arranged in each sheath layer, if a large bending force is applied to the cord as previously mentioned, these steel filaments become scattered and abnormal input is created in a part of these steel filaments to cause breakage of the steel filament, whereby the life of the cord is undesirably shortened.

[0017] On the contrary, in the steel cord according to the invention, the number of steel filaments in the outermost sheath layer (second sheath layer) is made smaller by 1 or 2 filaments than the maximum number of steel filaments closely arranged on a circumscribed circle of the innermost sheath layer (first sheath layer), so that the steel filaments of the outermost sheath layer are restrained by a coating rubber penetrated into gaps between the steel filaments of the outermost sheath layer to develop an effect substantially equal to the use of the wrap filament. That is, the decrease of filament strength can be suppressed to control the shortening of the life of the cord upon the application of large bending force.

[0018] According to the invention, the steel cord preferably has a 1 + 6 + 11 three-layer twisting construction as shown in Fig. 1.

[0019] If the number of steel filaments in the outermost sheath layer is smaller by 3 or more filaments than the maximum number of steel filaments closely arranged on a circumscribed circle of the innermost sheath layer, deviation of the steel filaments is apt to be caused in the outermost sheath layer and the production of such a cord becomes very difficult.

[0020] When six steel filaments as a first sheath layer are twisted around a single steel filament as a core layer, if all of these steel filaments have the same filament diameter, the sectional shape of the first sheath layer is substantially ellipsoidal due to the twisting of these steel filaments around the core, so that the contact pressure between the steel filaments of the first sheath layer increases to lower the fatigue resistance of the steel filaments in the first sheath layer.

[0021] Therefore, it has been confirmed that it is effective to prevent the degradation of fatigue resistance by making the filament diameter in the core layer thicker than the filament diameter in the first sheath layer to lower the contact pressure between the filaments of the first sheath layer. However, if the difference of the filament diameter between the core layer and the first sheath layer is too large, the steel filaments of the first sheath layer may easily move around the core layer and hence the wearing of the core layer by fretting with these steel filaments increases to lower the fatigue resistance of the core layer. In order to solve this problem, according to the invention, the filament diameters in the core layer and the first sheath layer satisfy the following relationships:

$$Ds < Dc \leq 0.20$$

$$Ds \times 1.06 \leqq ((Dc + Ds) \times \pi)/6 \leqq Ds \times 1.1$$

wherein Ds is filament diameter of the sheath layer (mm) and Dc is filament diameter of the core layer (mm).

[0022] As the filament diameter becomes thicker even in the above cord, if an extremely large bending force is applied

to the cord, breakage of the filament is caused. In order to prevent such breakage, it is effective to reduce the surface strain of the steel filament. In general, the surface strain ε of the steel filament is approximated to $\varepsilon = D/2R$ (where D is filament diameter, and R is radius of curvature in the bending of the cord). That is, in order to reduce the surface strain ε of the steel filament under a constant bending force R, it is effective to make the filament diameter D as small as possible.

[0023] In this connection, the inventor has confirmed from various experiments that the filament diameter causing no breakage of the steel filament is not more than 0.20 mm when an extremely large bending force is applied to the carcass ply cord in a heavy duty pneumatic radial tire, particularly a low-section profile pneumatic radial tire having an aspect ratio of not more than 80%. That is, when the filament diameter exceeds 0.20 mm, the surface strain undesirably increases.

[0024] In order to ensure the necessary cord strength by making the filament diameter as small as possible, according to the invention, two sheath layers are disposed around the core layer. If three or more sheath layers are formed on the core layer, the twisting construction becomes more complicated, and particularly it is very difficult to form these sheath layers in the same twisting direction. Moreover, it is preferable to use so-called high strength steel wire filament having a tensile strength of not less than 333 kg/cm^2 as the steel filament.

[0025] The following examples are given in illustration of the invention and are not intended as limitations thereof.

[0026] There are provided several low-section profile radial tires for trucks and buses to be tested, each having a tire size of 11/70R22.5 14PR.

[0027] In the tire according to the invention, a steel cord of three-layer twisting construction as shown in Table 1 and Fig. 1 (1 + 6 + 11 twisting construction) is used at an end count of 22 cords/5 cm in a radial carcass ply, in which numeral 1 is a steel filament constituting a core layer, numeral 2 a steel filament of a first sheath layer and numeral 3 a steel filament of a second sheath layer. In the comparative tires, a steel cord of three-layer twisting construction provided with a wrap filament (1 + 6 + 12 + 1 twisting construction) as shown in Table 1 and Fig. 2 (numeral 4 is a wrap filament) is used in Comparative Example 1, and a steel cord of 1 + 6 + 12 twisting construction as shown in Table 1 is used in Comparative Example 2, and steel cords of 1 + 6 + 11 twisting construction not satisfying the relationship of filament diameter between core layer and sheath layer defined in the invention are used in Comparative Examples 3-5, respectively.

[0028] The retention of tensile strength of the cord after usual running, and percentage of filament breakage and fretting depth after running under a large bending force are measured with respect to these test tires by the following evaluation methods to obtain results as shown in Table 1.

(1) Retention of tensile strength in cord

[0029] The test tire subjected to an internal pressure of 8 kgf/cm^2 is run on a drum at a speed of 60 km/h under a JIS 100% load according to the usual manner. Thereafter, 10 carcass ply cords are taken out from the tire, and breaking strengths thereof are measured by means of an Instron type tensile testing machine to determine an average value thereof. The retention of tensile strength of the cord is evaluated by dividing the above average value by an average value of breaking strengths of 10 cords taken out from a new tire.

(2) Fretting depth

[0030] After the test tire is run on the drum under the above conditions, the carcass ply cord is taken out from the tire and then two steel filaments are taken out from each layer constituting the cord. Thereafter, the reduction of filament diameter due to fretting or fretting depth Df as shown in Fig. 3 is measured in a region of 14.5 cm ± 2 cm centering around an equatorial plane to obtain results as shown in Table 1, in which a maximum value is adopted for the comparison.

(3) Percentage of filament breakage

[0031] After the test tire subjected to an internal pressure of 1 kgf/cm^2 is run on the drum at a speed of 60 km/h under a JIS 40% load (i.e. condition of large bending force) over a distance of 10,000 km, 10 carcass ply cords are taken out from the tire, and then the number of broken filaments is measured. The percentage of filament breakage is represented by a percentage of dividing the number of broken filaments by total filaments of 10 cords. The smaller the numerical value, the better the percentage of filament breakage.

Table 1

	Example 1	Comparative Example 1	Comparative Example 2	Example 2	Example 3	Comparative Example 3	Comparative Example 4	Comparative Example 5
Twisting construction	1+6+11	1+6+12+1	1+6+12	1+6+11	1+6+10	1+6+11	1+6+11	1+6+11
Filament diameter (mm)	0.185/0.17 /0.17	0.185/0.17 /0.17/0.15	0.185/0.17 /0.17	0.165/0.155 /0.155	0.185/0.17 /0.17	0.17/0.17 /0.17	0.20/0.17 /0.17	0.23/0.21 /0.21
Ds × 1.06	0.1802	0.1802	0.1802	0.1643	0.1802	0.1802	0.1802	0.2226
Ds × 1.10	0.1870	0.1870	0.1870	0.1705	0.1870	0.1870	0.1870	0.2310
((Ds + Dc) × π)/6	0.1859	0.1859	0.1859	0.1675	0.1859	0.1780	0.1937	0.2304
Judgment of condition *1	○	○	○	○	○	×	×	○
Twisting direction	∞/S/S	∞/S/S/Z	∞/S/S	∞/S/S	∞/S/S	∞/S/S	∞/S/S	∞/S/S
Twisting pitch (mm)	∞/5.5/11	∞/5.5/11/3.5	∞/5.5/11	∞/5.5/11	∞/5.5/11	∞/5.5/11	∞/5.5/11	∞/6/12
Retention of tensile strength in cord	99	86	97	99	98	92	94	98
Fretting depth (max: μm) *2	9 (second sheath)	34 (second sheath)	9 (second sheath)	8 (second sheath)	10 (second sheath)	18 (first sheath)	22 (first sheath)	10 (second sheath)
Percentage of filament breakage (%)	0	0	21	0	0	0	1	78

*1: $D_s \times 1.06 \leqq ((D_s + D_c) \times \pi)/6 \leqq D_s \times 1.10$, ○ satisfy, × not satisfy

*2: The parenthesis in fretting depth indicates the position of steel filament showing maximum value.

[0032] As mentioned above, in the steel cord according to the invention, the wearing of the steel filaments in the outermost sheath layer of the cord due to fretting with a wrap filament is reduced owing to the absence of the wrap filament, and decrease of the filament strength in the cord is suppressed to improve the service life of the cord. When the steel cord according to the invention is applied to the carcass ply of a heavy duty pneumatic radial tire, the tire durability is improved.

Claims

1. A steel cord for the reinforcement of rubber articles having a three-layer twisting construction comprising a core layer comprised of a single steel filament (1), a first sheath layer comprised of six steel filaments (2) arranged around the core layer, and a second sheath layer comprised of steel filaments (3) of number subtracted by 1 or 2 filaments from the maximum steel filament number arranged on a circumscribed circle of the first sheath layer, in which the said steel filaments in the first and second sheath layers are twisted in the same twisting direction at a different twisting pitch without using a wrap filament, and characterized in that filament diameters of the core layer and the sheath layers satisfy the following relationships:

$$Ds < Dc \leq 0.20$$

$$Ds \times 1.06 \leq ((Dc + Ds) \times \pi)/6 \leq Ds \times 1.1$$

wherein Ds is filament diameter of the sheath layer (mm) and Dc is filament diameter of the core layer (mm).

2. A steel cord as claimed in claim 1, characterized in that the steel filament (1; 2; 3) is a high strength steel wire filament having a tensile strength of not less than 330 kg/cm^2.

3. A heavy duty pneumatic radial tire having a carcass ply comprised of steel cords and having an aspect ratio of not more than 80%, characterized in that said steel cord is as claimed in claim 1 or 2.

Patentansprüche

1. Stahl cordfaden zur Verstärkung von Gummierzeugnissen, der eine Dreischicht-Verdrillbauweise hat, aufweisend eine Kernschicht, die aus einem einzigen Stahlfilament (1) besteht, eine erste Mantel schicht, die aus sechs um die Kernschicht herum angeordneten Stahlfilamenten (2) besteht, und eine zweite Mantelschicht, die aus Stahlfilamenten (3) besteht, deren Anzahl um 1 oder 2 Filamente geringer ist als die maximale Anzahl der auf einem Umkreis der ersten Mantelschicht angeordneten Stahlfilamente, wobei die Stahl filamente bei der ersten und zweiten Mantel schicht in der gleichen Verdrillrichtung mit einer verschiedenen Verdrillsteigung verdrillt sind, ohne ein Wickelfilament zu verwenden, dadurch gekennzeichnet, daß die Filamentdurchmesser der Kernschicht und der Mantel schichten die folgenden Beziehungen erfüllen:

$$Ds < Dc \leq 0{,}20$$

$$Ds \times 1.06 \leq ((Dc + Ds) \times \pi)/6 \leq Ds \times 1{,}1$$

wobei Ds der Filamentdurchmesser der Mantel schicht (mm) ist, und Dc der Filamentdurchmesser der Kernschicht (mm) ist.

2. Stahlcordfaden wie in Anspruch 1 beansprucht, dadurch gekennzeichnet, daß das Stahlfilament (1; 2; 3) ein hochfestes Stahldrahtfilament ist, das eine Zugfestigkeit von nicht weniger als 330 kg/cm^2 hat.

3. LKW-Radialluftreifen, der eine aus Stahlcordfäden bestehende Karkassenlage hat, und ein Querschnittsverhältnis von nicht mehr als 80% hat, dadurch gekennzeichnet, daß der Stahlcordfaden ein Stahlcordfaden ist, wie er in Anspruch 1 oder 2 beansprucht wird.

Revendications

1. Câblé en acier pour le renforcement d'articles en caoutchouc, ayant une construction à torsion de trois couches comprenant une couche centrale composée d'un seul filament d'acier (1), une première couche de gaine composée de six filaments d'acier (2), agencés autour de la couche centrale, et une deuxième couche de gaine composée d'un nombre de filaments d'acier (3) inférieur de 1 ou de 2 filaments au nombre maximal de filaments d'acier agencés sur un cercle circonscrit de la première couche de gaine, lesdits filaments d'acier dans les première et deuxième couches de gaine étant tordus dans la même direction de torsion, avec un pas de torsion différent, sans utilisation d'un filament d'enveloppement, caractérisé en ce que les diamètres du filament de la couche centrale et des couches de gaine sont conformes aux relations ci-dessous:

$$Ds < Dc \leq 0,20$$

$$DS \times 1.06 \leq ((De + Ds) \times \pi)/6 \leq Ds \times 1,1$$

   où Ds représente le diamètre du filament de la couche de gaine (mm), Dc représentant le diamètre du filament de la couche centrale (mm).

2. Câblé en acier selon la revendication 1, caractérisé en ce que le filament d'acier (1; 2; 3) est un filament de fil d'acier à résistance élevée ayant une résistance à la traction non inférieure à 330 kgf/cm^2.

3. Bandage pneumatique pour poids lourds comportant une nappe de carcasse composée de câblés en acier et ayant un rapport d'aspect non supérieur à 80%, caractérisé en ce que ledit câblé en acier est conforme aux revendications 1 ou 2.

FIG_1

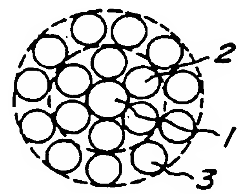

FIG_2

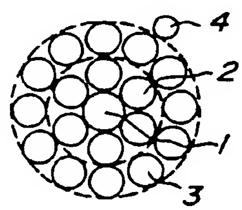

FIG_3